NEW SHOREHAM BRIDGE
(Bridge No. 140)
Beach Road, spanning Harbor Pond
New Shoreham
Washington County
Rhode Island

HAER No. RI-42

HAER
RI
5-NESH,
2-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
Philadelphia Support Office
U.S. Custom House
200 Chestnut Street
Philadelphia, P.A. 19106

HAER
RI
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HISTORIC AMERICAN ENGINEERING RECORD

NEW SHOREHAM BRIDGE
(Bridge No. 140)

HAER No. RI-42

Location: Beach Road
Spanning Harbor Pond
New Shoreham, Washington County, Rhode Island

UTM: 19.284700.4561590
USGS Quadrangle: Block Island, RI, 1:24000

Date of Construction: 1917

Designer: Clarence Hussey
Chief Engineer, Bridge Department
R.I. State Board of Public Roads
(R.I. Department of Transportation)

Present Owner: State of Rhode Island
Department of Transportation
Two Capitol Hill - Room 372
Providence, Rhode Island 02903

Present use: Vehicular and pedestrian bridge

Significance: The New Shoreham Bridge is the earliest intact example of a reinforced concrete T-beam bridge in Rhode Island. Built under the adverse conditions of isolated location, material scarcity due to World War I, and unfavorable weather; the bridge was designed by Clarence Hussey, the first State Bridge Engineer of the Rhode Island State Board of Public Roads and nationally-recognized authority on bridge engineering. It was determined eligible for listing in the National Register of Historic Places on May 11, 1992 through consensus between the RISHPO and the Federal Highway Administration.

Project Information: The New Shoreham Bridge is structurally deficient due to deterioration of the T-beams and scouring of the abutment walls and wingwalls. Replacement of the T-beams and integral slab would effectively replace the bridge. It has been determined that the bridge must be replaced (1996). A Memorandum of Agreement was ratified by the RISHPO, FHWA and the Advisory Council on Historic Preservation on March 20, 1995. The MOA includes a stipulation requiring HABS/HAER documentation. This report was prepared to satisfy that stipulation.

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HISTORICAL BACKGROUND

The Historic Landscape of Block Island

In September 1993 the Rhode Island Historic Preservation and Heritage Commission prepared materials for a Consensus Determination of Eligibility for the National Register of Historic Places entitled "The Historic Landscape of Block Island." This document, as well as the earlier *Historic and Architectural Resources of Block Island, Rhode Island* (1991), provide a description of the area surrounding New Shoreham Bridge No. 140. The district was determined eligible for listing in the National Register of Historic Places through consensus between the RISHPO and the Federal Highway Administration on May 27, 1994. New Shoreham Bridge is individually listed in the National Register; it is also a contributing resource in the Block Island Historic Landscape District.

The Crossing

Historic map images of Block Island indicate that the boundaries of Harbor Pond, Trims Pond, Great Salt Pond and the adjoining land areas have changed considerably over the last 150 years. The 1850 Henry F. Walling map of Block Island shows a continuous body of water comprising Great Salt Pond, Harbor Pond and Trims Pond; the 1862 Walling map indicates three distinct ponds connected by streams. Eight years later, the Beers Atlas map shows an approximately 300 foot wide area separating Harbor and Trims Pond with a footpath indicated in the vicinity of the present Beach Avenue. A later map, published in Livermore's *Block Island Illustrated* (1893 edition), indicates distinct, although interconnected, ponds, with Beach Avenue following the approximate location of the earlier footpath. The Sanborn Map of 1886 shows an unnamed "public road" in the same location. By 1909 the Sanborn Map refers to this road as "Hygeia Road," named after the Hygeia Hotel. The construction of this road sometime before 1886 required a crossing of Harbor Pond.

Rhode Island State Board of Public Roads (SBPR) documents describe a circa 1900 wooden beam bridge called the "Salt Pond Bridge, No. 140" in the *Annual Report* for 1914 and the "Middletown Road Bridge, No. 140" a year later. The reason for this change in names is unclear. Wooden bridges often had a short life of ten to fifteen years--especially in a climate like that of Block Island; if the SBPR's dating of the circa 1900 bridge is correct, it may have been the second wooden highway bridge at that location.

Rhode Island's Concrete Bridges

In 1892 the Rhode Island General Assembly appointed a committee to assess the State's road conditions. In a report delivered to the General Assembly three years later, the Committee "found very little to commend."[1] The eventual result of this survey of some 2420 miles of inadequate roads was the establishment of a State Board of Public Roads (SBPR) in 1902.

The rapid rise of automobile use in the period from 1900 to 1915 spurred many states to establish highway departments. With a pressing need to quickly replace great numbers of deficient or inadequate bridges, these agencies turned to standardized designs that could be easily adapted to the specific characteristics of span, foundation, roadway, and intended use.

In 1912 the Rhode Island General Assembly enacted a Bridge Law calling on the SBPR to examine the 156 bridges located on the State's public roads. Upon completion of this assessment the SBPR was to supervise the construction, replacement or repair of any bridges "lying in or on upon the State roads which had been improved by the State"[2] since the formation of the Board ten years earlier. The investigation would be carried out by a newly-formed Bridge Department under Chief Bridge Engineer Clarence L. Hussey.

Clarence Hussey was an advocate of concrete bridges. The first reinforced concrete bridge on a Rhode Island public road and constructed under State supervision, the Flat River Bridge in Coventry, had served the State well--and maintenance free--since 1907.[3] In light of this success story, one of the first tasks of the Bridge Department was to standardize a system of reinforced concrete bridge design, a system in which basic designs could be adapted to the varied circumstances of the many bridges on Rhode Island's roads.

Hussey addressed the problem of rural bridgework in the *Annual Report* of January 1916:

> A serious problem is presented to the department in the construction of small isolated bridges, which, taken in the aggregate, make up a considerable part of the work of the department. Such structures do not warrant the use of extensive equipment, highly paid skilled labor, or disproportionate engineering expense; yet small structures of a permanent character must rest on stable foundations of sufficient capacity to care for floods and future traffic.[4]

Hussey's expectations of serious difficulties were realized in the replacement of a small isolated bridge near the Old Harbor on Block Island.

The Middletown Road Bridge

Among the 156 bridges inspected by the Bridge Department were 52 wooden beam structures with spans ranging from 5 feet to 40 feet in length. Numbered among them was the "Middletown Road Bridge No. 140"[5] over a tidal passage between Harbor Pond and Trims Pond on Block Island. The bridge was photographed and inspected by the SBPR in December 1913. The Bridge Department identified it as requiring replacement in the January 1915 *Annual Report*:

> The Middletown Road Bridge...should be rebuilt during the coming year. It is an old wooden beam bridge of 28 foot span, reported to have been built 15 years ago with second-hand stock. The piling which now supports the structure is in dangerous condition, being honeycombed below highwater mark by the attack of marine borers. In several cases the tops of the piles have decayed.[6]

Beyond the deficiencies described above, the Bridge Department was to find out during the dismantling of the wooden bridge (1917) that the stringers were broken apart and "the structure was only able to carry the lightest traffic." Replacement with a "slab or girder type of structure" at a projected cost of $3000 was projected in January 1916. Despite the immediacy of the wooden bridge's structural faults, the SBPR conducted a second inspection and further repairs on the bridge later that year.

Manuscript records of the SBPR indicate that a request for construction bids for a concrete bridge was published late in 1916. A sole bid of $14,000 was submitted by Drake and Quillen, a Providence construction firm. Hussey attributed the lack of bidder interest to the isolated location. At the January 6, 1917 meeting of the SBPR the Drake and Quillen bid was rejected as too costly; the Board chose instead to construct the bridge by "force account." In fact, the New Shoreham Bridge was the first SBPR bridge built in this manner--the SBPR acted as prime consultant, directly hiring subcontractors and directly supervising and inspecting construction.

Construction plans were completed by late May 1917; actual construction began in mid-August of the same year. The bridge was substantially completed by November. The great discrepancy between the 1916 projected construction cost of $3000 and a final cost of $12,541 is due in large measure to the U.S. entry into World War I and the difficulties of construction in an isolated area. Shortly after the 1918 Armistice, Clarence Hussey described the difficult conditions that the Bridge Department had faced during the War:

> Construction costs were more than double those of normal times, available materials were limited and labor was scarce and inclined to be inefficient....Our Bridge Department was crippled by the loss of several men entering military service...and for a short time the supervising engineer was without any assistance for bridge inspection.[7]

His specific comments on the construction of the New Shoreham Bridge reveal a broad range of difficulties: soft foundation, tidewater, a lack of skilled labor, erratic transportation, isolated location, no local equipment, a lack of soft coal, and a limited supply of local lumber. Moreover, sand suitable for saltwater construction could be found only at one location in the center of the island. The transportation company normally retained by the SBPR refused to transport supplies and equipment, necessitating the hiring of a schooner for the purpose. In summation Hussey stated, "The New Shoreham Bridge...was constructed under the most adverse conditions that have ever confronted our organization."[8]

T-Beam Bridges

To address these difficulties a "modified girder" or "T-beam" bridge was designed. In this monolithic structure a series of eight small concrete beams were poured simultaneously with the slab that formed the bridge deck. In 1912 the Bridge Department's typical replacement for a span of the length required at Harbor Pond would have been a reinforced concrete arch.[9] This decision to substitute a T-beam for an arch bridge eliminated the need for arch centering and reduced by 20% the amount of concrete required for the superstructure.[10] The employment of a T-beam design was not, however, a Rhode Island highway innovation: a year earlier Kentucky's Road Department had adopted the T-beam bridge as its standard for spans with a range of from 16 feet to 30 feet.

A significant variation on the standard T-beam bridge was the embedding of a steel railroad rail in each of the eight beams of the New Shoreham Bridge. It is unclear whether this was a wartime economy necessitated by the scarcity of materials, as steel mesh and 3/4" or 1/2" reinforcement was used liberally throughout the rest of the bridge.[11] The New York New Haven & Hartford Railroad (NYNH&H) was in the process of a general upgrading of its lines for heavier loadings at the time of the construction of the bridge.[12] This upgrading included the replacement of 80 lb. with 100 lb. rails. As a result, obsolete rail was probably readily available at the time, its tensile strength adding considerably to the strength of the T-beams. Because this was a relatively untried type of bridge in the Rhode Island road system, the insertion of heavy rails was likely a conservative design measure.

Such measures were, however, in keeping with an admonition published by The American Concrete Institute's Committee on Reinforced Concrete Bridges and Culverts in a contemporary description of T-beams:

> This type of construction consists in the use of small beams, spaced closer together than in the deck girder type, and covered with a thin floor slab which furnishes the compression area of the girder T-beams....While the yardage is less [than that of a deck girder type] the sections are much thinner than the slab type, and, if chosen, this type should undoubtedly be subjected to the most rigid inspection and constructed with carefully selected materials.[13]

The challenge of a soft foundation was addressed by the innovation of a "split-pile foundation." A typical pile is driven to bedrock; but the lack of a hard foundation at Harbor Pond forced the Bridge Department to excavate the abutment areas, place "split piles" (piles with splayed extensions to better attach themselves to the surrounding sand) in position, and backfill. These engineering solutions--both innovative and cost efficient--were characteristic of the work of Clarence Hussey.

Concrete, Steel Reinforcement, and Salt Water

By 1925 SBPR inspection photos show serious concrete abrasion and wear on the wingwalls. A matter of growing concern among engineers, the effects of salt water on reinforced concrete were the subject of a series of articles in *Engineering News-Record* in the fall of 1917. The extensive use of concrete in seacoast construction since the turn of the century had raised some questions in the minds of Rudolph Wig of the U.S. Bureau of Standards, and Lewis Ferguson of the Portland Cement Association.

Between 1915 and 1917 Wig and Ferguson conducted a nationwide tour of concrete installations on the Atlantic, Pacific and Gulf Coasts. Their inspections were supplemented by a questionnaire to determine, where possible, details of construction method, mix proportions, salt content of water used, and exposure conditions. Among the 146 sites surveyed, the authors inspected six Navy sites in Newport, Rhode Island.

The survey results, expanded upon in a series of five articles, pointed to several culprits in the often rapid deterioration of coastal reinforced concrete. These included, among others, chemical variables in the curing process, physical variables of the mix, and relative skill of the laborers involved in the work. The central problem, however, turned out to be mechanical abrasion. The conditions of abrasive, moving water; the normal porosity of the material; the penetration of salt water into tiny porous chambers left in the curing process; the subsequent freezing and expansion of that water; and, finally, the penetration of water and salt into the steel reinforcement all combine to destroy reinforced concrete. Oftentimes the destructive process was well on its way within weeks of construction.[14]

More recent studies tend to corroborate these early findings. While Wig and Ferguson dismissed electrolytic factors in 1917, recent research suggests that this is a major destructive factor. A 1991 *Atlantic Monthly* article describes the process:

> Once the concrete has survived the effects of a few freezes, the salts bleed down to the steel reinforcing bars, where the combination of salt and steel creates an electrochemical reaction akin to that in a battery, causing severe rusting at one electrical pole. As the rust expands, it pops out chunks of the surrounding concrete, further exposing the steel bars to corrosion.[15]

The conditions described above are well demonstrated in the persistent problems of abrasion, spalling concrete, and rusted reinforcement on the New Shoreham Bridge.

SIGNIFICANCE

Concrete Bridges

The use of concrete as a construction material dates to the Hellenistic period when Greek engineers used it in the building of aqueducts. Concrete's first wide use is, however, associated with the Romans, who combined locally available volcanic sands with lime and aggregate as early as 200 BC. This combination provided a durable material, often used in combination with masonry or brickwork, that survives to the present in surprisingly good condition. Although there is evidence of the use of bronze rods for reinforcement,[16] Romans used concrete primarily as a masonry substitute, a material strong in compression but weak in tension.

Concrete fell into disuse during the Middle Ages and was not reintroduced until the mid 18th century. In 1840 Joseph Aspdin produced "Portland" cement by the careful measurement and mixing of limestone and clay. The resulting stone-like material resembled the Portland building stone commonly used in England, hence the name. While Portland Cement, mixed with aggregate to make concrete, was superior to its ancient counterpart, it was not until the mid-19th century reintroduction of metal reinforcement that concrete came to be used as a material with strength in tension as well as compression.

By 1870 French engineers had employed reinforced concrete in the construction of arches for the La Vanne Aqueduct, part of the Parisian water supply.[17] On this side of the Atlantic, Ernest Ransome built the first reinforced concrete arch bridge in San Francisco's Golden Gate Park in 1889. Although this bridge represented a significant advance in bridge construction, its conservative design and surface treatment evoked the masonry types that preceded it. By the turn of the century, a new generation of bridge designers would begin to grasp the structural potential of reinforced concrete and begin to design to those possibilities.

Clarence L. Hussey

Relocating to Providence after his graduation from Massachusetts Institute of Technology in 1908, Clarence L. Hussey worked in various capacities in the engineering field before joining the R.I. State Board of Public Roads in 1912. The Board had recently established a Bridge Department to oversee the design, construction, and maintenance of the State's highway bridges. Hired as Chief Bridge Engineer, Hussey had a profound influence on bridge design and construction throughout the state between 1912 and 1925.

An expert in the relatively new field of reinforced concrete construction and a nationally-recognized bridge engineer, Hussey formulated new, stronger concrete mixes and applied this knowledge to innovative and cost-saving bridge designs. One of the most notable of these innovations was the modified arch bridge, a design that saved as much as 50% of the concrete normally required for a span of comparable size. The modified arch had inclined, rather than vertical, spandrel walls and sidewalks and railings that were carried on brackets anchored to the arch ring. In the words of an American Society of Civil Engineers remembrance of Hussey published after his death in 1925, "His ideas, although marked by striking originality, had the saving virtue of reasonableness."[18] Hussey designed the Washington Bridge between Providence and East Providence, the original span of which still carries eastbound traffic over the Seekonk River. He also designed the only concrete through arch bridge in Rhode Island. Completed in the last year of his life, it spans Wickford Cove and is appropriately named the Clarence L. Hussey Memorial Bridge.

DESCRIPTION

The New Shoreham Bridge carries Beach Road over a narrow tidal passage connecting Harbor Pond and Trims Pond. The latter empties into Great Salt Pond, which in turn empties into Block Island Sound. The bridge is a single span reinforced concrete structure of the T-beam type, an early 20th century adaptation of a concrete deck girder, in which the beams, running parallel to the roadway, are poured simultaneously with the deck. The deck girder typically has a small number of substantially-sized beams and a large separation between them. The T-beam variation of this design uses a comparatively greater number of beams, smaller in section, with a correspondingly smaller separation between them. This smaller beam depth allows for greater clearance over the feature crossed with little sacrifice of strength.

The 1917 New Shoreham Bridge is the second bridge of this type built by the Bridge Department of the R.I. State Board of Public Roads (see attached inventory). Although seriously damaged by almost 80 years of extreme weather conditions and proximity to salt water, It is substantially intact, retaining much of the appearance of the original construction.

Substructure: The bridge is 32' long, with a span of 25 1/2'. The abutments are 30" thick, 40' wide, and 17' high, resting on spruce piles. The wingwalls are tapered vertically 18" to 24", and outward from the abutment 18" to 13". They extend 17' from the abutments at a 45 degree angle.

Superstructure: The eight beams, running parallel to the roadway, are 19" deep and 40' long. The six outer beams are 4'6" on center; the two center beams are 3' on center. At their lowest point the beams are 6" thick, tapering outward to 12" at the underside of the 4" deck. An inverted steel rail runs the length of each beam, embedded in concrete approximately 1" at the lowest point of the beam. The web of each rail was drilled to accept a 3/4" reinforcement bar. This bar was attached to #23 triangle mesh embedded in the underside of the deck slab. At the bottom of these beams spalling concrete reveals the rusted steel rails.

The 35'6" wide roadway is bound by concrete curbs and parapet walls on both the north and south sides of the span; these add another 4'6" of width to the span for an overall width of 40'. The underside of the bridge beams are 6' above mean tide level. The roadway fill above the deck is approximately 24" deep at the crown, paved with asphalt. It has been resurfaced several times since the bridge's construction in 1917. While there is no evidence of the original streetcar rails remaining on the north section of the bridge's roadway, a section of rail still protrudes from the soil on the west approach to the bridge. The

8' wide timber bed designed to carry these rails may still be under the roadway's dirt fill. As was typical for remote, rural bridges in the early R.I. road system, there are no paved sidewalks on the New Shoreham Bridge. There is, however, an approximately 7' unpaved path on both sides of the 20' asphalt roadway. A standard, ribbed steel guard rail is attached to the four corners of the bridge.

The entire parapet wall consists of a lower section that forms the 10" curb, and a thinner section above the curb height that forms the railing. The lower parapet is 22" thick, rising 33" above the upper surface of the deck. At this height a thinner railing rests on this 22" surface. This upper section is 12" thick and 27" high. This height includes a 6" cap that increases in width to 16" over the end pilasters. An inverted rail, inserted at the base, runs the length of the parapet.

The northwest and southeast pilaster ends carry the bronze numerals embedded in the concrete indicating the date of construction: 1917. The northeast and southwest pilaster ends carry the numerals indicating the SBPR bridge number: 140. This practice of marking the date and State bridge number was developed by Clarence Hussey and used between 1912 and 1917. There are only a few bridges remaining in the State with bronze numerals from this period. After 1917 the SBPR adopted the blue and white ceramic identification tiles seen on many bridges throughout Rhode Island.

Aesthetic treatment: A central tenet of modernism, as embraced by designers early in the 20th century, was the belief that the form of a structure should reveal its function clearly and simply. In this spirit, the Bridge Department wrote in 1916:

> The designs prepared for State bridges are practically devoid of ornament and this condition makes the proportion and balance of the masses of a plain structure more important; and in consequence the lines and proportions of the new bridges have been carefully studied.[19]

This attention to line and proportion--even in the case of a remote rural bridge--is evident in the design of the parapet walls of the New Shoreham Bridge. The end pilasters are 39" long; the three recessed panels are separated by a 24" section of raised concrete. Of the three 1" deep recesses, the two outer panels are 6'10" wide; the center panel is 8' wide. This scheme echoes the designs popularized by Daniel Luten.[20] Luten insisted that, in any succession of three or more concrete arches, the span of the central arch should be increased to obviate the visual foreshortening that naturally occurs when viewed at a distance.

Though lacking any surface ornamentation, the bridge's parapet walls are treated with two types of concrete finishes. The recessed panels are "bush-hammered," a rough finish that reveals much of the aggregate stone. The raised portions of the parapet walls were originally rubbed or "polished" to a smooth concrete finish with little aggregate evident. Though still visible, these distinctions in surface treatment are subtle now due to years of exposure to weather.

Inventory of Rhode Island Historic Concrete T-Beam Bridges (15)

Date	Name/Number	N.R. Status
1909	Waterman Ave. RR (#945)	Potentially eligible
1913	Hopkins Mills Bridge (#96)	Potentially eligible
1917	**New Shoreham Bridge (#140)**	**Determined eligible***
1919	Van Zandt Avenue (#287)	Determined eligible*
1920	Wakefield Bridge (#20)	Not eligible
1921	North Scituate Bridge (#93)	Potentially eligible
1925	Pontiac Avenue (#201)	Determined eligible*
1926	Pocasset River Bridge (#23)	Potentially eligible
1930	Austin Farm Bridge (#15)	Determined eligible*
1932	Pawcatuck Bridge (#22)	Determined eligible*
1932	Capron Road (#792)	Potentially eligible
1936	Weekapaug Bridge (#997)	Determined eligible
1939	Esmond-Georgiaville (#159)	Determined eligible*
1940	Central Bridge (#182)	Not eligible
1942	Louisquisset Pike (#276)	Not eligible

Notes:

The original deck of the Waterman Avenue Railroad Bridge (1909) was widened by the addition of two concrete beams on its south side. This bridge was not built by the SBPR.

The Hopkins Mills Bridge (1913), identified in early SBPR records as a two-span "T-beam/Slab" bridge, combines a concrete superstructure with partial concrete/masonry abutments and center pier. The lower level of uncoursed masonry appears to date to an earlier crossing.

The Van Zandt Avenue Bridge, the Capron Road Bridge, and the Louisquisset Pike Bridge are of the continuous T-beam type.

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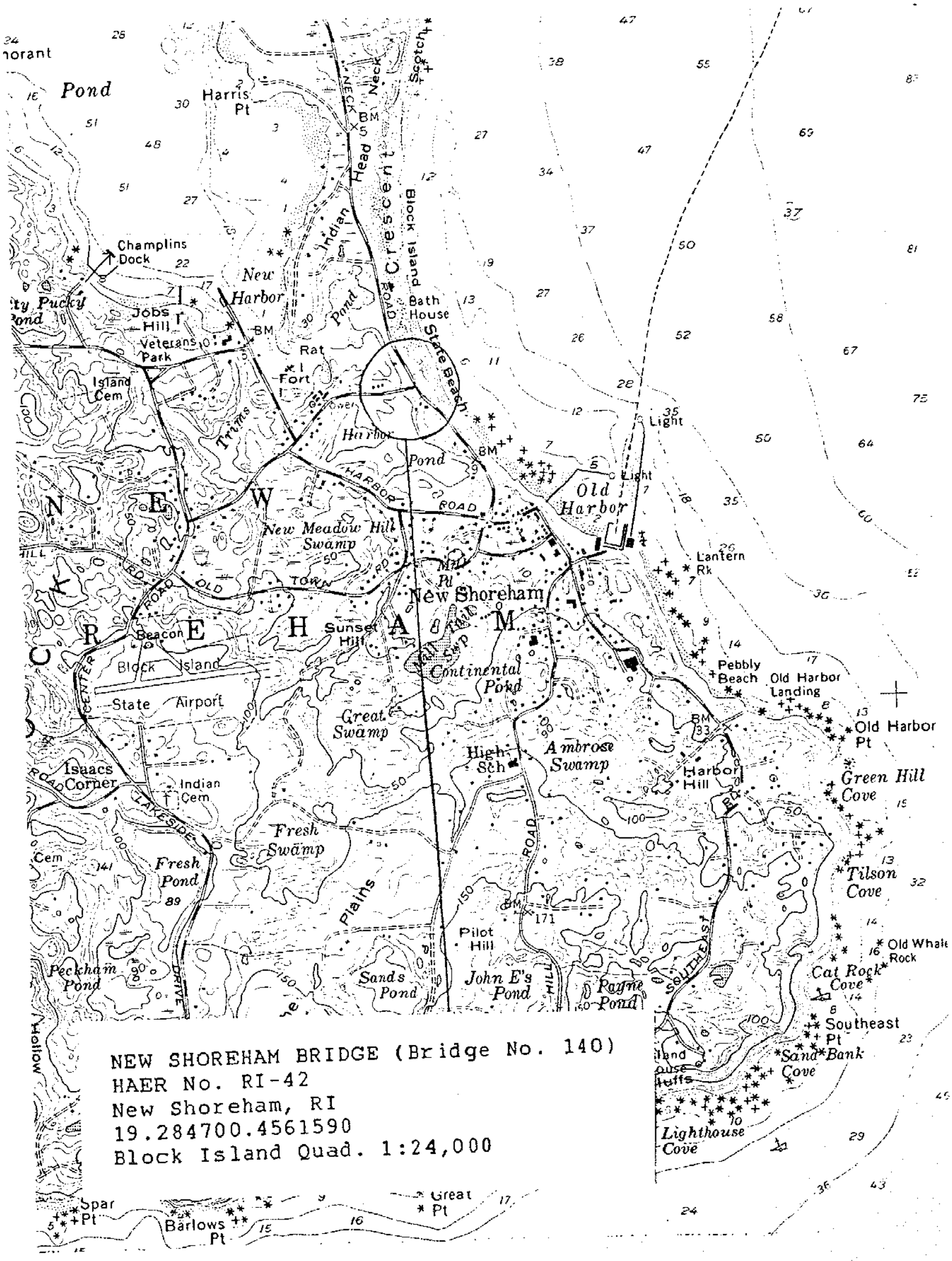
* Determined eligible through consensus between RISHPO and FHWA.



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New Shoreham, RI
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Block Island Quad. 1:24,000

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Engineering Drawings:

Four original construction drawings for New Shoreham Bridge are on file at the Rhode Island Department of Transportation, 2 Capital Hill, Providence, Rhode Island.

Historic Views:

43 black and white photographs (approximately 5.5" x 3.25" format) documenting the inspection, construction and repairs of New Shoreham Bridge are also on file at the R.I. Department of Transportation. The corresponding negatives are on file at the Rhode Island State Archives, Westminster Mall, Providence, R.I.

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The Historic Landscape of Block Island. R.I. Historic Preservation and Heritage Commission. Providence: 1993

Likely sources not yet investigated:

Block Island sources describe a collection of historic images in the possession of Robert Downie, a past year-round resident. This collection is said to include images of the New Shoreham Bridge. Downie is out of the area at this time and the collection is in storage and unavailable to researchers.

NOTES

1. *Report on the Roads and Public Highways of Rhode Island.* Providence: E.L. Freeman, 1895.

2. *Eleventh Annual Report of the R.I. State Board of Public Roads* (January 1913): 29

3. This bridge, a 75' reinforced concrete arch (No. 71), was removed in 1954 because of its narrow 16' wide roadway. RIDOT Construction photos made during its replacement indicate that it was still structurally sound at the time of its demolition.

4. *Fourteenth Annual Report of the R.I. State Board of Public Roads* (January 1916): 51

5. At the time of the 1913 survey, the SBPR called the crossing "Middletown Road." Later maps identify the crossing as Beach Road.

6. *Thirteenth Annual Report of the R.I. State Board of Public Roads.* (January 1915): 51-2

7. *Seventeenth Annual Report of the R.I. State Board of Public Roads* (January 1919): 55

8. ibid p. 56

9. Reinforced concrete arches were used for spans of from 5' to 75' in length. For example, the Browning Mill Bridge in Exeter, a wooden bridge of 24 foot span--similar to that of Bridge 140--was replaced in 1913 by a concrete arch.

10. "Kentucky Road Department has Standard Bridges." *Engineering News-Record* 79 (9 August 1917): 255-6

11. For a discussion of the use of rails in concrete bridge work, see "Concrete trestles have I-beams and rails in slabs." *Engineering News-Record* 79 (27 September 1917): 591. For a discussion of earlier examples of entire truss bridges constructed of old rail, see "A Bridge Built of Old Rails," *Railroad Gazette* 26 (30 November 1894) and a subsequent letter to the editor (14 December 1894): 845.

12. For a discussion of the rail line upgrading and wartime conditions see *Providence Magazine* (June 1917): 359.

13. "Preliminary Report of the Committee on Reinforced Concrete Bridges and Culverts." *Proceedings of the American Concrete Institute* 12 (1916): 410

14. See Rudolph Wig and Lewis Ferguson, "What is the Trouble with Concrete in Sea Water?" *Engineering News-Record* 79 (20 September 1917): 532

15. See John Sedgwick, "Strong But Sensitive." *Atlantic Monthly* 267 (April 1991): 73

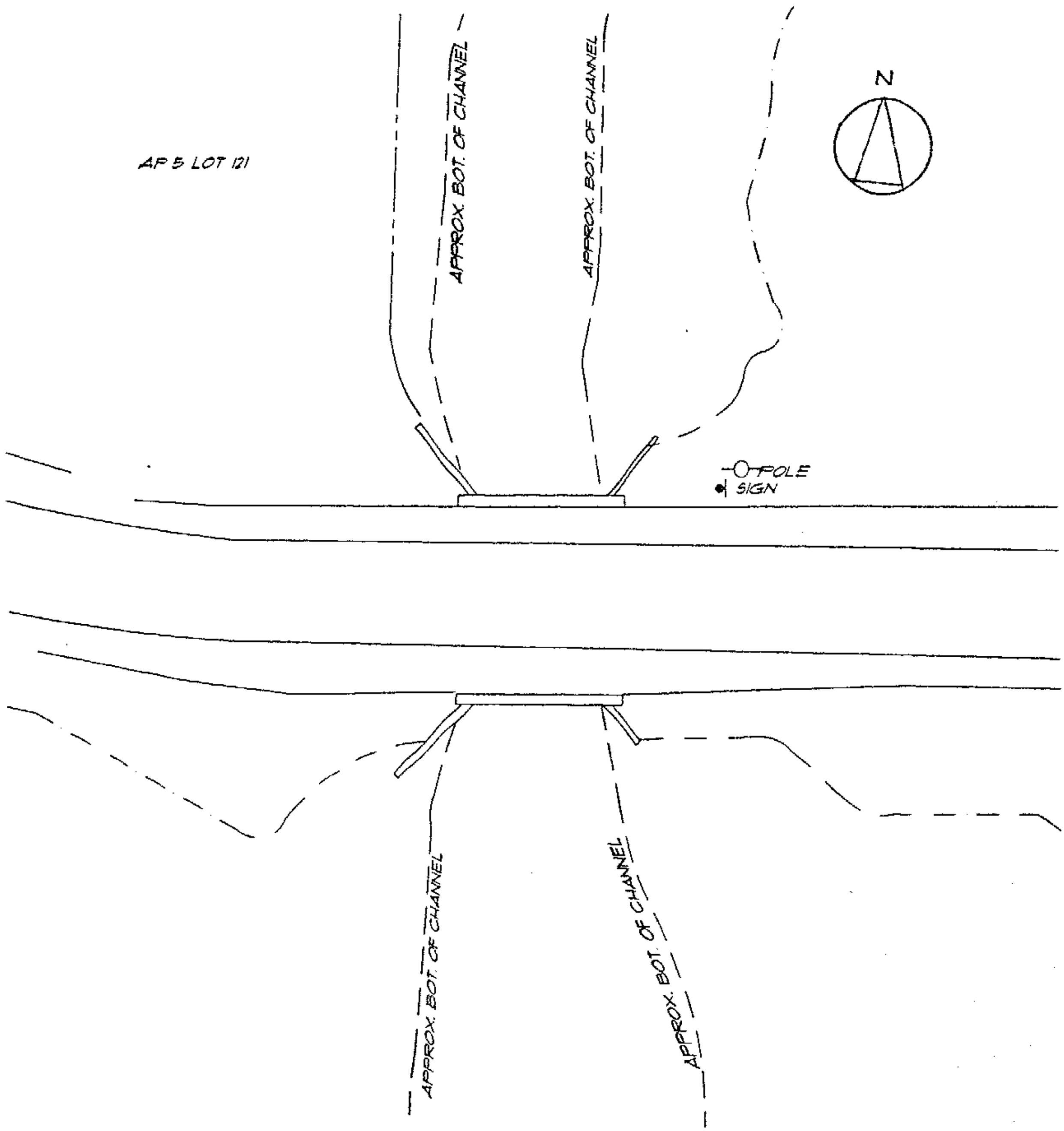
16. Harrison Howe, *The New Stone Age* (New York: The Century Co., 1921), pp. 85-86

17. This structure of some 135 miles was intended to be built of masonry and cast iron. The chief engineer of the project, a M. Belgrand, chose to use the *beton-agglomore* of Coignet for a 37-mile section of the aqueduct notable for its difficult topography. For a thorough discussion of the project see "The Aqueduct of La Vanne." *The Manufacturer and Builder* 2 (May 1870): 143-5,. While the use of reinforcement is not discussed in this article, it is briefly mentioned in Harrison Howe, *The New Stone Age,* New York: The Century Co., 1921, p. 86

18. George Henderson, "Memoir of Clarence Loring Hussey," *Transactions of the American Society of Civil Engineers* (1926): 1632-33

19. *Fourteenth Annual Report of the State Board of Public Roads* (January 1916): 50

20. Luten was a nationally-recognized concrete bridge designer retained as a consulting engineer by the SBPR at the time of the creation of the Bridge Department in 1912. The SBPR originally paid royalties for the use of the "Luten System" of concrete bridge designs. Later in the decade Luten's proprietary claims were weakened by the widespread use of generally-available bridge plans as well as the success of several lawsuits contesting these claims.



SKETCH PLAN
Approximate Scale: 1" = 30'